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ON THE VARIATION OF CURRENT WITH DISTANCE BETWEEN THE ELECTRODES OF A GLOW DISCHARGE IN GASES AT LOW PRESSURE

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(*Received for publication, June 24, 1949*)

ABSTRACT. Measurement of current strength with variation of distance between the electrodes of a glow discharge reveal that with the anode in the negative glow the current shows a maxima before falling to zero when the anode reaches the boundary of the cathode dark space. In the present paper it is suggested that when the anode is in the negative glow a stream of positive ions flows from the negative glow to the cathode dark space, which is not inconsistent with the assumptions of Sir J. J. Thomson.

INTRODUCTION

According to Sir J. J. Thomson's theory (1905) the glow discharge, in a gas at low pressure, is maintained by the continuous liberation of the secondary electrons from the cathode surface by the bombardment of the positive ions, that are produced wholly in the cathode dark space by the electrons. Aston (1911), Geddes (1925), and Guntherschulze (1923-24) also working on electric discharge through gases under similar conditions found the dark space to be the most active region of the glow. Observations by Schuster (1890) and Wehnelt (1890) on the formation of shadows on the cathode by placing solid obstacles in the dark space and the diminution of the thickness of the cathode dark space by the application of a magnetic field at right angles to the discharge studied first by Guntherschulze (1924) support very much the theory put forward by Thomson.

Different explanations have, however, been given by various experimenters with respect to the supply of the positive ions which bombard the cathode surface and thus maintain the discharge. Ryde (1923) holds that the supply of positive ions to the cathode dark space is mainly from the negative glow which acts as an emitter and the cathode as a collector. Loeb (1939) believes that there is always a rush of the positive ions from the negative glow to the cathode dark space. Compton and Morse (1927) assume that the flow of the positive ions from the negative glow will take place particularly when the discharge is abnormal. Compton's view is probably based on the fact that in an abnormal discharge the ionisation in the dark space is much less intense than in the normal case and it is, therefore, likely that a part of the supply of the positive ions may be from the negative glow. No sufficient experimental evidence is, however, available to substantiate these views.

A detailed study of the variation of current with the distance between the electrodes of a glow discharge under different conditions of pressure and voltage can only throw light on this problem. Thomson (1931) observed that if the distance between the electrodes is much greater than the thickness of the cathode dark space and the anode is gradually moved towards the cathode without disturbing the pressure in the tube, no change in the current is observed till the anode reaches very near to the boundary of the cathode dark space when the current begins to fall very rapidly as the distance between the electrodes is decreased and it requires a very small further diminution in the distance to stop the discharge altogether These observations which were probably carried out at lower voltages, as is evidenced by our observations, substantiated his theory

No systematic work appears to have been done which may throw sufficient light on this problem. The author has, therefore, carried out experiments under various pressures and voltages to study in greater detials the variation of the current with the anode at different distances from the cathode in order to throw further light on the mechanism of the maintenance of the glow discharge.

APPARATUS

The main apparatus consisted of a discharge tube of pyrex glass 5 cms. in diameter sealed at its two ends by means of sealing wax to two hollow brass cases fitted with a fixed and a movable electrode—both being brass discs of 4 cms. diameter and 3 mm. thickness. The upper movable electrode was made to move up and down by the rotation of a brass rod *r* sealed firmly

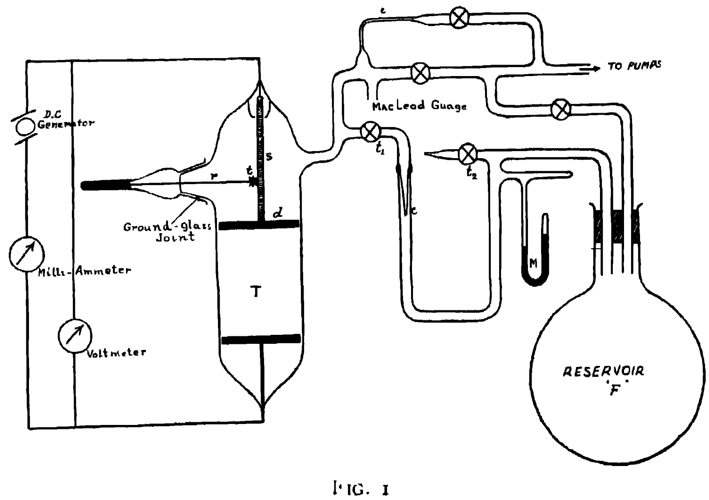

FIG. 1

in a ground glass joint by means of sealing wax. The rod r has a toothed wheel t at its other end, the teeth of which were fixed in the groves of the stem s fitted with the disc d. The arrangement was such that a motion of even a fraction of a millimetre was practicable without disturbing the pressure in the discharge tube.

In order to maintain a desired pressure in the discharge tube the apparatus was fitted with a 'leak system'. A flask F of a considerable capacity was connected to the main apparatus through a leak of a very finely drawn capillary c. The reservoir F was also connected to the pumps and could be exhausted to any desired pressure.

The apparatus was exhausted by Gaede's all-steel mercury diffusion pump backed by a Cenco Hyvac pump, and then the leak, c, was connected to the main apparatus by opening the stop cock t_1 and at the same time the discharge tube was also connected to the pumps through another capillary e. After a short time the gas entering and leaving the tube regulates its flow resulting in the maintenance of a constant pressure in the discharge tube. As the pressure in the discharge tube depends on the pressure in the reservoir, it can be varied by altering the pressure in the reservoir. The pressure adjusted by this method remains constant for several hours.

The pressure of the discharge tube was measured by a M'cleod gauge connected to the main apparatus The distance between the electrodes was measured by means of a cathetometer.

EXPERIMENTAL PROCEDURE AND RESULTS

Having obtained the steady pressure in the discharge tube, the electrodes were connected to a D C motor-generator and were kept at a fairly good distance. The readings of current and voltage were taken when they attained a constant value The upper electrode was then gradually moved towards the cathode and its positions with the current and voltage were recorded at different distances. The movement was made slower when the variation in the current took place till the discharge went off At a constant pressure a number of sets of observations with different voltages were taken.

At lower voltages the current remains practically constant by the gradual decrease in the distance between the electrodes till the anode reaches very near the boundary of the cathode dark space when it begins to fall rapidly and goes off abruptly for further diminution in the distance between the electrodes. At higher voltages, however, the current does not remain constant, but increases when the anode enters the negative glow till a certain stage comes when it attains a maximum value and then on further decreasing the distance, the current begins to fall and the discharge goes off. The maximum is always very near to the boundary of the cathode dark space. The increase in the current is followed by a decrease in the voltage and vice-versa. The increment of current was found proportional to the voltage.

The graphs between current and distance between the electrodes show that the current after reaching the maximum value decreases approximately to the same value, which it had when the distance between the electrodes was fairly large. Observations are given graphically in Figs. 2, 3, 4 and 5.

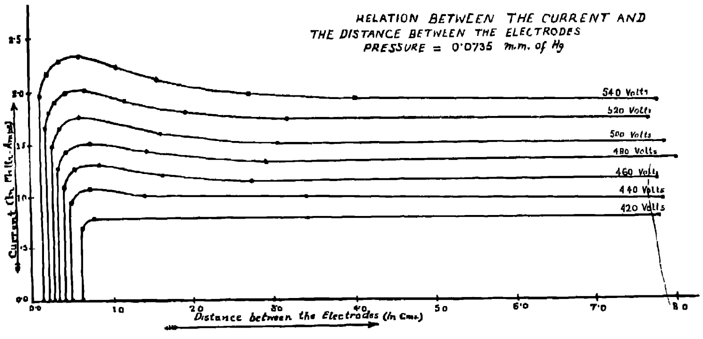

FIG. 2

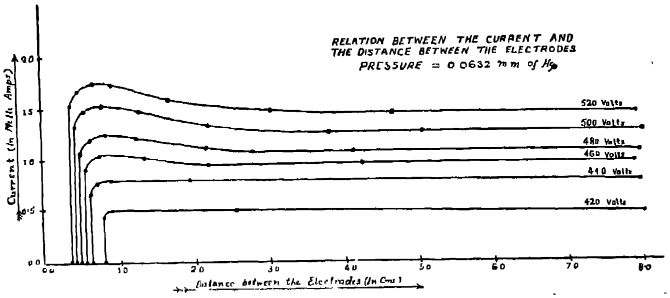

FIG. 3

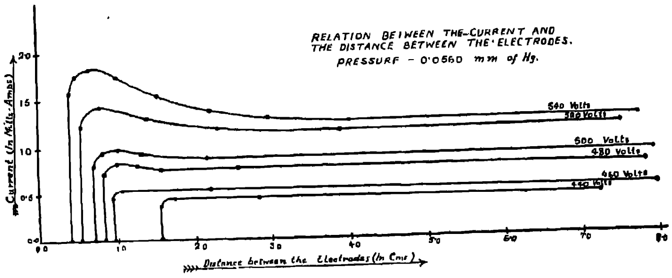

FIG. 4

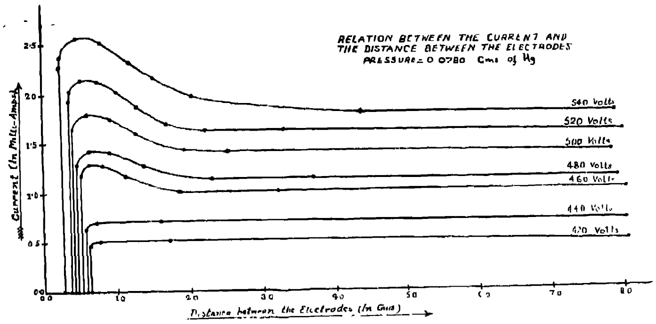

FIG. 5

DISCUSSION OF RESULTS

Thomson believes that positive ions flowing to the cathode come wholly from the cathode dark space. On this assumption there should be no change in the discharge current when the distance between the electrodes is gradually decreased till the anode reaches the boundary of the cathode dark space. At the slightest decrease in this distance the current should at once drop to zero.

Observations by the author confirm this fact to a great extent at only lower voltages when the current strength is very low. At higher voltages the current begins to increase when the anode reaches the negative glow In every curve there is a maximum which is always very near the boundary of the cathode dark space. The current then begins to decrease rather rapidly and falls to zero for the slightest decrease in the distance when the anode is on the boundary of the dark space. As the curves show that the rate of rise of the current is proportional to the voltage applied at a constant pressure ; it can perhaps be assumed that the same phenomenon occurs even at lower voltages but cannot be detected on account of the insensitivity of the detecting instrument for variation of current of this order.

"The electric force in the negative glow is exceedingly small, so small that it is doubtful if whether have at present the means of determining it with any approach to accuracy." (Thomson, 1933). Hence the density of the positive ions is approximately equal to that of electrons in this region. As there is no force sufficient to drag the positive ions and the electrons away, there will be a great loss of ions due to their recombination. This should hold only so long. as the anode is at a sufficiently large distance from the cathode, *i.e.*, away from the region of the negative glow. When the anode enters the negative glow, the electrons present in this region are attracted by it. On account of its potential according to Langmuir and Mott-Smith (1924), these electrons do not act as a sheath in front of the anode but pass into it. Thus a number of electrons, that would have been lost due to recombination in the negative glow in the absence of the anode in that region, will now pass on to it, giving an increase in the current. Also the positive ions present in the negative glow will be repelled when the anode reaches there and will tend to move towards the cathode dark space. This will result in sending a stream of positive ions from the negative glow into the cathode dark space Thus the ions reaching the cathode will increase giving a rise in the current As the anode will move towards the dark space the number of ions entering the cathode dark space will also go on increasing till a stage will come when most of the negative glow will be cut off and the ions present in the remaining portion of the dark space will themselves decrease, causing a diminuation in the number of ions entering from the negative glow to the cathode dark space There will be practically no ions in the negative glow that can be sent to the dark space when the anode reaches very near to its boundary and hence the current should be the same as it was when the anode was at a fairly large distance from the cathode. Thus a kink should be observed in current-distance graph. The increment of the current should be proportional to the voltage as the force required to send the ions to the cathode dark space from the negative glow increases with the increase of the voltage.

This shows that for fairly large distances between the electrodes the positive ions striking the cathode come wholly from the dark space and a very few may enter from the negative glow ; but when the distance is such that the anode is in the region of the negative glow the positive ions continuously flow from it to the cathode dark space. Thomson's assumption, is, therefore, true for only large distance between the electrodes For such small distances there must also be a potential gradient in the negative glow and there must be a deviation from Aston's law for the electric force in the cathode dark space.

Experiments with different electrodes in different gases are still in progress.

ACKNOWLEDGMENT

The author is under deep sense of gratitude to Dr. Sh. Nawazish Ali, Chairman, Department of Physics Muslim University, Aligarh, for his continuous assistance and valuable suggestions without which this work could not be completed.

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